SHORT COMMUNICATION

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A diagenesis to metamorphism transition in the Hercynian of north-west Spain

THE Iberian Massif of the north-west of Spain has been divided into two main zones (Lotze, 1945), the West-Asturian–Leonese and Cantabrian zones, on the basis of sedimentological and structural criteria. These zones define an arc, called the Asturian arc or knee, with the concavity towards the Cantabrian zone (fig. 1), which is formed of a pre-Carboniferous platform sequence with several unconformities, overlain by a well-developed Carboniferous sequence. Precambrian rocks only outcrop at the western boundary. This external zone is characterized by deformation of a superficial type, practically without metamorphism or plutonism and with only local cleavage development. The structure of the zone is the result of a general decollement of the Palaeozoic sequence. The West-Asturian–Leonese zone (fig. 1) is characterized by a thick Cambrian to Silurian sedimentary sequence, which is mainly pelitic but has important quartzitic horizons, especially in the Cambrian and Lower Ordovician. Post-Silurian rocks range from early Devonian to Stephanian and occur in only a few, usually small, outcrops. The Precambrian rocks outcrop in the core of the largest antiform structure, limiting the zone in the east and west. In this West-Asturian–Leonese zone, deformation is accompanied by a multi-facies regional metamorphism and the widespread occurrence of cleavage. Most of the rocks are in the greenschists facies, although in the western part the sillimanite isograd is reached. Plutonism, represented mainly by small post-tectonic stocks, is concentrated in the western part of the zone.

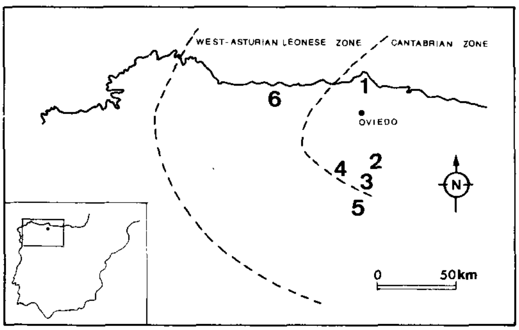

FIG. 1. Simplified map of north-west Spain, showing location of sampling areas: 1, Cabo de Peñas; 2, Central Coal Basin; 3, Barrios de Luna; 4, Somiedo nappe; 5, Narcea Anticlinorium; 6, Tapia area.

Data on low-grade metamorphism in both zones are scarce, but in the last few years some localized information about the metamorphism in the Cantabrian Mountains has been obtained (Perez-Estaun, 1978; Bastida and Pulgar, 1978; Brime and Perez-Estaun, 1980; Brime, 1981; Aller and Brime, 1983). The object of this note is to describe new data and to provide regional information based on clay mineralogy, measurement of the crystallinity of illite and white mica b_0 data.

Experimental. The methods of sample preparation and measurement of illite crystallinity are essentially those of Brime (1981) but in the present note measurements of peak-width are given in units of degrees 2θ Cu-$K\alpha$. The values corresponding to the low and high grade limits of Kubler's (1967, 1968) anchizone are respectively 0.55 and 0.35° 2θ and have been established by measurement of oriented aggregates prepared for standards kindly provided by Dr G. Dunoyer de Segonzac. The criteria for sample collection and the analytical procedure used for the measurement of b_0 was that proposed by Sassi (1972), Sassi and Scolari (1974) and Guidotti and Sassi, (1976).

Mineralogy. X-ray analysis of the clay minerals in the $< 2\,\mu$m fraction has displayed the presence of diversified mixtures ranging from various irregular and regular illite/smectite mixed-layers, illite, smectite, kaolinite and paragonite to the simple illite and chlorite mixtures characteristic of the epizone. Pyrophyllite may be also present.

The distribution of these argillaceous minerals indicates a transformation trend in which the grade increases towards the internal part of the belt, i.e. towards the west in the northern part of the Asturian arc and towards the south in the southern part. The following changes have been observed: (1) disappearance of kaolinite and mixed-layer illite/smectite; (2) increase in the amount of chlorite;

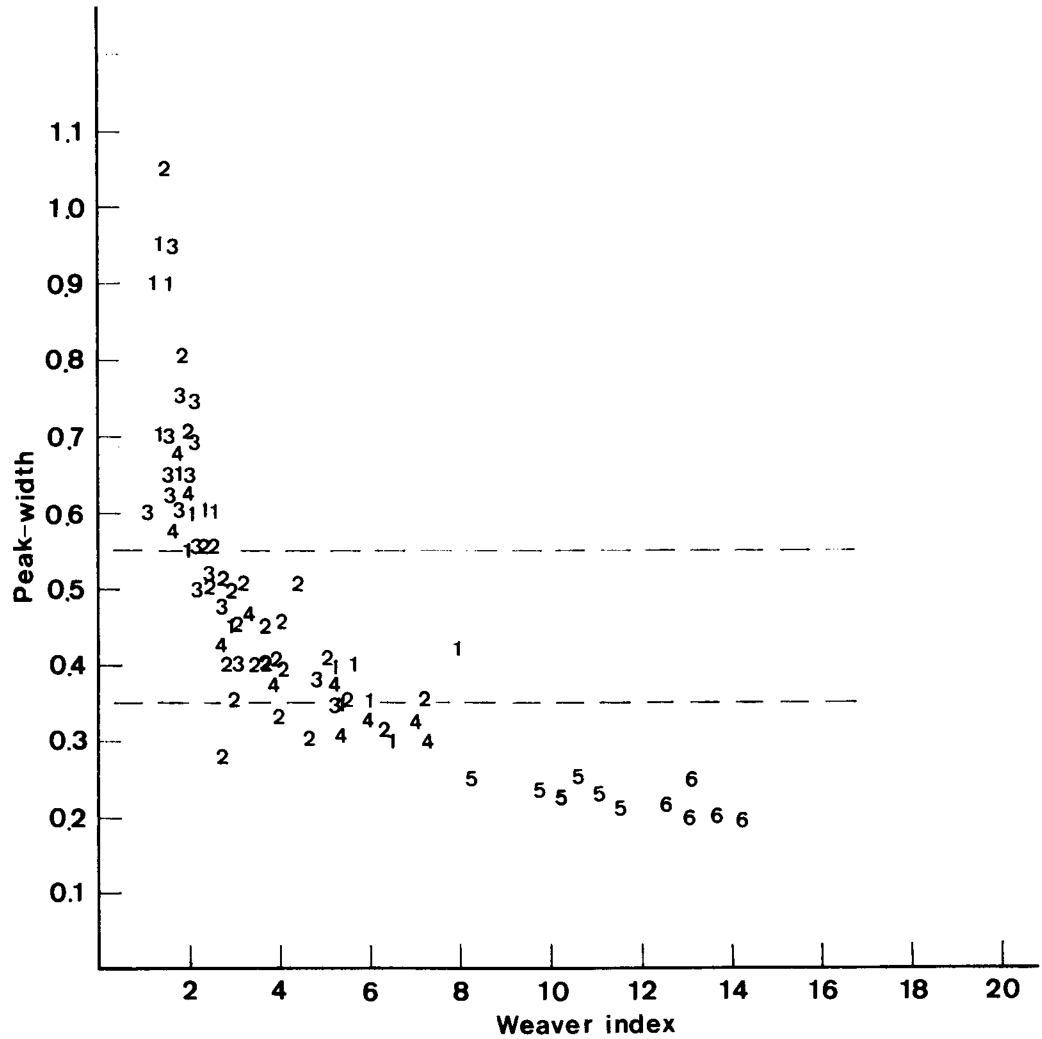

FIG. 2. Kubler index (peak-width) *vs.* Weaver index, sample numbers as for fig. 1.

(3) restriction of paragonite and paragonite/muscovite mixed-layer to rocks of the higher anchizone.

Recrystallization of illite. Measurement of illite crystallinity confirms that the metamorphic grade increases towards the internal parts of the massif. The change is from diagenesis (IC = 1.0° 2θ) to the onset of epimetamorphism (IC = 0.2° 2θ) (figs. 2 and 3). The epimetamorphic conditions are reached at different places in the Cantabrian zone (fig. 3) and are always related to tectonic events. In Cabo de Peñas (fig. 1, area 1, and fig. 3) and the Central Coal Basin (fig. 1, area 2, and fig. 3) the changes occur in a wide area with the gradient increasing from east to west in the former and north to south in the latter. In both cases the change is closely related to the development of the cleavage in the pelitic rocks (Brime and Perez-Estaun, 1980; Aller and Brime, 1983). In the other two areas studied Barrios de Luna (fig. 1, area 3, and fig. 3) and Somiedo (fig. 1, area 4, and fig. 3) the changes are related to the emplacement of nappes.

In the West-Asturian-Leonese zone the pelitic rocks sampled in the southern part of the Narcea Anticlinorium (fig. 1, area 5, and fig. 3) and in the Tapia area (fig. 1, area 6, and fig. 3) are in the epizone but there are no diagnostic minerals to indicate the pressure of metamorphism.

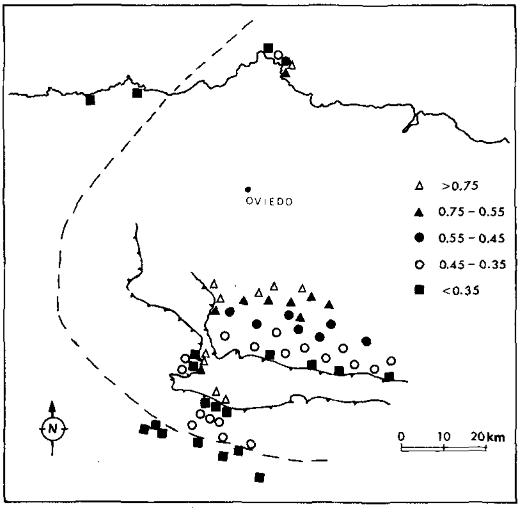

FIG. 3. Distribution of the crystallinity of illite: values in degrees 2θ Cu-$K\alpha$.

b_0 values. The procedure used here for recognizing the baric type of metamorphism is that based on the b_0 values of K-white micas. Measurement of the b_0 value has been made in localities where the metamorphic degree ranges from anchimetamorphic to the biotite zone (fig. 4), and it has been found that the mean b_0 value increases with metamorphic grade (Table I). Group 1 gives values of b_0 slightly lower than the others. Several causes may be assumed as responsible for this lower b_0 value, e.g. the very low-temperature conditions of this group; small bulk compositional differences as the samples from this group and those of group 2 fall into high-Al assemblages (fig. 4) and will thus show a low celadonitic content; small changes in αH_2O etc. However the differences are so small as to be unimportant for interpretation. A preliminary sampling made at the garnet and andalusite zones shows that in those zones the b_0 value is very similar to that encountered in the biotite zone, indicating that the increase of b_0 with the metamorphic grade is not a continuous process (Table I). The highest b_0 value obtained was 8.99 Å, which is well below the limit generally accepted for the onset of intermediate-pressure conditions (fig. 5) (Sassi, 1972; Sassi and Scolari, 1974). These pressure conditions agree well with those established by other authors (Capdevilla, 1968, 1969) for the

Table I. Number of samples, mean b_0 values and standard deviation (s) for each sample group

Group Metamorphic grade	No of samples	$\bar{b}_0$ (Å)	s
1. Limit Anchi - Epizone	30	8.954	0.005
2. Greenschist	10	8.961	0.004
3. Biotite zone	30	8.986	0.004
4. Garnet zone	10	8.970	0.006
5. Andalusite zone	14	8.977	0.004

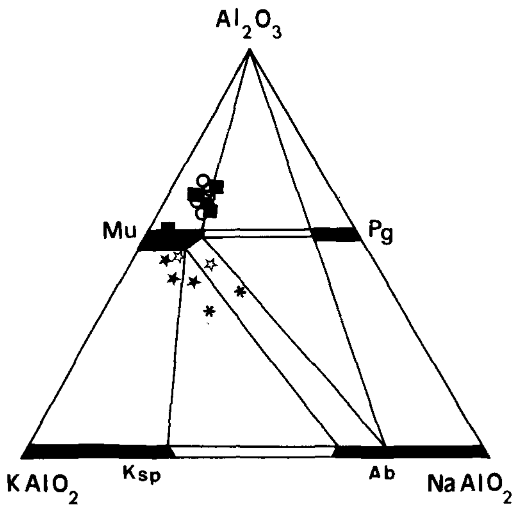

FIG. 4. Schematic AKNA diagram showing the mineral compatibilities for metapelites. The points indicate approximately the composition of the samples utilized for the b_0 measurement of muscovites (o Anchi-epizone; ■ Greenschists; * Biotite zone; ✫ Garnet zone; ✶ Andalusite zone).

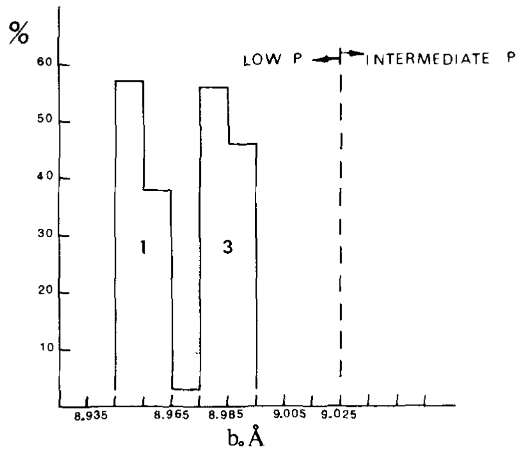

FIG. 5. Frequency histograms of the b_0 values of white micas from the limit anchi-epizone, Cabo de Peñas (1) and the biotite zone (3).

regional metamorphism of the West-Asturian-Leonese zone.

Application of the b_0 geobarometric method to the rocks of the Cantabrian and West-Asturian-Leonese zones indicates a low-pressure metamorphism, consistent with its Hercynian origin (Zwart, 1969) and with the presence of pyrophyllite together with kaolinite (Winkler, 1979) in the Cabo de Peñas area.

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